Thin Layer Test Pavements in Denmark
- Project description

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1. Preface

Around 20% of the homes in Denmark are exposed to road traffic noise that exceeds the recommended national guidelines of 55 dB (as L_{Aeq,24h}). In the Danish national strategy for a sustainable development from June 2002 [1] it can be read, that noise from road traffic is a widespread local problem for the environment and the healthiness. Many people are living in areas where the noise from road traffic exceeds the limits, which can be seen as acceptable for the health. In the strategy there is a long time goal, that the transport noise shall be reduced to a level which ensure that nobody are exposed noise that can give considerably negative effects to the health.

In all the European countries road traffic noise causes annoyance among many of the residents. The noise problems are to some extend concentrated in the urban areas where the speed on most of the roads is around 40-60 km/h, but there are also serious noise problems along highways.

There is a great need to develop effective noise reducing tools that are durable, safe and cost-effective. The noise can be reduced either by the source, under propagation or at the receiver. An effective way to reduce noise and avoid annoyance is to reduce the emission at the source. The rolling noise is generated when the tires are rolling on the pavements. The type and structure of the road pavement is very important for the determination of level of the noise emitted.

In August 2002 the European SILVIA project was started. The title of the project is Sustainable Road Surfaces for Traffic Noise Control [1]. One of the objectives of SILVIA is to evaluate and specify road construction and maintenance techniques that would achieve satisfactory durability of acoustical performances of noise reducing road surfaces while complying with other requirements of sustainability i.e., safety, pollution, fuel consumption, structural durability and costs. The SILVIA project is partly financed by EU and partly by national sources. 14 partners from research institutes, universities, public institutions and private companies from 10 European countries are working together in this comprehensive three year project.

The Danish Transport Research Institute is the Danish partner in SILVIA. But due to reductions in budget the institute have subcontracted all the work. Until springtime 2004 the work was subcontracted to ATKINS Denmark. Since the summer of 2004 the work has been subcontracted to Danish Road Directorate/Danish Road Institute.

The work plan of SILVIA consists of 6 work packages:

- WP1: Management.
- WP2: Classification methods.
- WP3: Cost/benefit analysis.
- WP4: Low noise, durable pavements.
• WP5. Integration of noise reducing pavements with other noise abatement measures.
• WP6 Exploitation and dissemination.

The work in work package 4 is focused on investigation on existing and testing of new noise reducing pavement materials, technologies and maintenance methods to produce guidelines on how to design, build and maintain sustainable noise reducing road surfaces that retain their good acoustic performance over time. As a part of working package 4.3 it have been decided to carry out a subproject in Denmark, where the goal is to develop and test open thin layers as noise reducing pavements under Nordic conditions (without studded tiers). As a nickname this Danish project is called “SILVIA.dk”.

In order to carry out SILVIA.dk a Danish project group have been established. Experts from research institutes, public institutions as well as the road pavement industry have been invited to be part of the working group. The project group have the following members:

• Civil engineer M.Sc. Lene Michelsen, Danish Road Directorate.
• Chemical engineer B.Sc. Jørn Raaberg, Danish Road Directorate/Danish Road Institute.
• Civil engineer M.Sc. Jørgen Horstmann, Danish Environmental Protection Agency.
• Technology Manager Jørn Bank Andersen, Danish Association of Asphalt Contractors and NCC Roads.
• Technical Manager Ole Grann Andersson, Skanska Asphalt.
• Civil engineer M.Sc. Steen Kønigsfeldt, Road and Park Division, Municipality of Copenhagen.
• Chief of Asphalt Laboratory Michael Rasmussen, Road and Park Division, Municipality of Copenhagen.
• Civil engineer M.Sc. Birte Nielsen, Road Department, Municipality of Århus.
• Civil engineer B.Sc. Birgit Berggrein, Road and Traffic, Environmental Division, Municipality of Randers.
• Civil engineer M.Sc. Jonas H. Olesen, Road and Traffic, Environmental Division, Municipality of Randers.
• Head of office Sven Aage Jensen, Road and Traffic, Environmental Division, Municipality of Randers.
• Senior Research Engineer Bent Andersen, Environmental Division, Atkins Denmark. From March 2004 Danish Road Directorate/Danish Road Institute.
• Senior Researcher Hans Bendtsen, Environmental Division, Atkins Denmark. From March 2004 Danish Road Directorate/Danish Road Institute.

The project group started the work at a meeting in April 2003. The leader of the project is Hans Bendtsen. This project description has been drafted by Hans Bendtsen on the background of discussions and input from the project group. This project description was approved by the project group at a meeting on the 3rd of September 2003.
Forord

I august 2002 startede det europæiske SILVIA projekt som hedder ”Sustainable Road Surfaces for Traffic Noise Control”. Som en del af SILVIA er det besluttet at gennemføre et delprojekt i Danmark. Formålet er at udvikle og teste tyndlagsbelægninger som støjreducerende belægninger under Nordiske betingelser, men uden brug af pigdæk. Projektet kaldes ”SILVIA.dk”. Dette notat indeholder en projektbeskrivelse for projektet.
2. Background

Different research projects have been carried out in Denmark over the last 15 years in order to develop noise reducing pavements. Single layer porous asphalt with a maximum aggregate size of 8 mm has been tested on urban roads and a highway [3]. At a highway where the speed limit was 80 km/h a noise reduction of 3-4 dB relative to a dense asphalt concrete with a maximum aggregate size of 12 mm was achieved over the lifetime of the pavement. On an urban road with a speed limit of 50 km/h a 3 dB noise reduction disappeared in a few years time, because the porous pavement was clogged [3].

In an ongoing Danish research project twin-layer porous pavements are tested on an urban road where the speed limit is 50 km/h (the so called “Øster Søgade project” in Copenhagen). The test sections were built in 1999. A comprehensive measurement program has been established. Noise, sound absorption, permeability, texture, built in air void and hardening of the binder is measured regularly [4]. Factors as traffic safety, cost-effectiveness and people’s perception of the noise reduction have been measured and/or analysed. After 4 years of measurements a porous pavement with 8 mm aggregates have a noise reduction of 4 dB for passenger cars relative to a dense asphalt concrete with a maximum aggregate size of 8 mm and a very smooth surface structure [5]. These pavements are high-pressure cleaned twice a year. It is planned to continue the measurement program over the lifetime of the pavements, if founds are available for such an activity.

In relation to noise twin-layer porous pavements so far seems to be a promising tool to reduce noise on urban roads. The study of cost effectiveness [4] showed, that the total costs to reduce the noise level 1 dB at a dwelling using twin-layer porous pavements is only around a fourth of the price of using facade insulation or noise barriers. This result is based on the assumption that the porous pavement will keep the noise reduction in the total lifetime of the pavement. This indicates that twin-layer porous pavements are a very cost-effective tool for noise reduction. But this type of pavement is anyway more costly to construct than ordinary pavements (that do not reduce the noise) because it is necessary to use two layers and as drainage system has to be established at the kerbside at urban roads.

On this background there is also a need to develop and test other cheaper types of noise reducing pavements that can be applied on urban roads (as well as on highways). Pavements that in construction cost are competitive to “ordinary” pavement types, and at the same time has a noise reducing capacity, even though it might not be as good as twin-lay porous pavements. In this new SILVIA.DK project it is the goal to develop and test such pavements.

In the recent years thin open pavements have been developed and tested as noise reducing pavements in the Netherlands. This new SILVIA.DK project will be based on the available Dutch results and will further develop and test thin open pavements.
under Nordic and Danish conditions. There are different reasons that the Dutch experiences can not be directly applied in a big scale on Nordic and Danish roads:

1. There is a need for further optimisation of the noise reducing capacity.
2. There are no long-time results on the noise reducing effect.
3. The local conditions might be different in relation to traffic, climate as well as road maintenance procedures.
4. There is a need to apply the thin layer noise reducing concept to the construction materials available on the local markets.
5. There is a need in the local asphalt contracting sector to develop and implement the new technologies.

It is the goal of the SILVIA.DK project to achieve the following main results:

- To gain knowledge for the joint European SILVIA project about the use of thin open layers under Nordic conditions (without studded tires).
- That thin open layers becomes an effective noise reducing tool on urban roads.
- That the Nordic road sector can use thin open layers for noise reducing tool on urban roads as well as on highways.
- That the asphalt contracting sector gets access to this new technology.
3. The concept of noise reduction

The generation of noise when the tires are rolling on a road surface are mainly determined by five different mechanisms [4]:

1. Vibrations in the tires. The vibrations are generated by the contact between the surface of the pavement and the rubber blocks of the tread pattern of the tire. The noise increases when the road surface gets rougher.

2. The air pumping effect. When the rubber blocks on the tread pattern of the tire hits the road surface air is pressed out of the cavities between the rubber blocks. When the rubber blocks leaves the road surface air is pumped back into the cavities. This air pumping to the surroundings generates noise. If the road surface is porous the air will instead be pumped down in the pavement structure and the noise will be reduced.

3. The horn effect. The curved tread pattern of the tires and the road surface acts as an acoustical horn which amplifies the road noise generated around the contact point between the tire end the road surface. If the road surface is porous and by that sound absorbing the amplification effect will be reduced.

4. Absorption under propagation. The engine and road-tire noise is propagated from the vehicles to the receivers. Under this propagation the noise will be reflected on the road surface. If the road surface is porous and by that sound absorbing the noise at some frequency bands will be reduced under the propagation.

5. The effect of stiffness. The stiffness of the pavement is important for the determination of the noise generated by the contact between the surface of the pavement and the rubber blocks of the tread pattern of the tire. If the pavement is less stiff the noise generated will be reduced.

On the background of the current knowledge it must generally be judged, that the first two mechanisms are the most important for the determination of the road tire noise.

The noise reducing effect of both single layer and twin-layer porous pavements comes basically from a reduction of the noise generation by the air pumping effect. When fine graded porous pavements with a smooth surface are used this also reduces the noise generated by the vibrations of the tires. In the recent Danish research projects about porous pavements aggregate sizes of 5, 8 and 12 mm have been used.

Porous pavements are open in the whole thickness of the layer with connected cavities. As a contrast to this, open pavements are open only at the upper part of the pavement with cavities having a depth less than the maximum size of the aggregates used for the pavement. The basic concept of using open pavements for noise reduction is to create a pavement structure, with as big cavities at the surface of the pavement as possible in order to reduce to some extend the noise generated from the air pumping effect, and at the same time ensuring a smooth surface so the noise generated by the vibrations of the tires will not be increased. Such a noise reducing open pavement can be thin, as the mechanisms determining the noise generation are only depended of the surface structure of the pavement.
4. Test roads

The municipalities of Copenhagen and Randers have been invited to participate in the project. They have both agreed to provide a test road for the project and to finance the construction of the test pavements. Afterwards the municipality of Århus have asked, if they could join the project. Århus was then invited to join the project group, and Århus has agreed also to provide a test road for the project, to finance the construction of the test pavements, to finance the noise measurements and to give the project group full access to the results.

The test sections had to be selected among the roads where the municipalities were planning to change the road surface within the next year. In order to ensure the best possible conditions for the project and especially for the SPB noise measurements a list of ideal criteria for the test roads was developed:

- The length of a section with a test pavement should be at least 75 m. A road with 3 test pavements and a reference pavement must be at least 300 m long.
- Speed between 50 and 60 km/h.
- A daily traffic of 6000 to 12000 vehicles.
- At least 8 % heavy vehicles (if possible with urban busses).
- A road in a horizontal plane without any gradient.
- A road with no curves or only curves with a very big radius.
- Traffic with an even driving pattern without acceleration or braking (good distance to intersections with traffic lights and to roundabouts).
- No important side roads with turning traffic.
- A uniform transversal profile (number of lanes, cycle lanes and sidewalks).
- Good acoustical condition at the transversal profiles at the selected measurement points:
  - No background noise sources with practical importance (as other roads).
  - No parking in front of the measurement positions (+/- 15-20 m) or a possibility to enforce parking restrictions during the measurement campaigns.
  - No well cover or the like in the wheel tracks in front of the measurement positions (+/-20-25 m).
  - Uniform acoustical reflection conditions at all the measurement positions. This means that it is preferable that the transversal profile including buildings is uniform on the whole test road:
    - No buildings on any of the two road sides.
    - Buildings on one roadside (all with the same distance to the centreline of the road).
    - Dense ribbon development on both sides of the road (ribbon development with the same distance to the centreline of the road).
- A low risk that repair work has to be carried out on the road during the whole test period (good standard and conditions for drain pipes, public heating pipes, gas pipes and telephone and electricity network).
After inspections of different roads the following three urban roads have been selected for the project:

- Kongelundsvej in Copenhagen.
- Udbyhøjvej in Randers.
- Søren Frichs Vej in Århus.

**Table 1. Data describing the test roads.**

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Road name</th>
<th>Length</th>
<th>Yearly daily traffic</th>
<th>Heavy vehicles over 3½ ton</th>
<th>Speed limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>Kongelundsvej</td>
<td>About 750 m</td>
<td>12.500</td>
<td>8,6 %</td>
<td>60 km/h</td>
</tr>
<tr>
<td>Randers</td>
<td>Udbyhojvej</td>
<td>About 600 m</td>
<td>6.660</td>
<td>8 %</td>
<td>50 km/h</td>
</tr>
<tr>
<td>Århus</td>
<td>Søren Frichs Vej</td>
<td>About 600 m</td>
<td>11.000</td>
<td>ca. 10 %</td>
<td>50 km/h</td>
</tr>
</tbody>
</table>

**Figure 1. Kongelundsvej in Copenhagen.** The road is situated in the southern outskirts of the city on Amager. Along the road there are allotment gardens and no houses close to the road.
Figure 2. Udbyhøjvej in the eastern part of Randers. Along the road there are detached housing and some three story blocks.

Figure 3. Søren Frichs Vej in Århus. Along the road there are some three story buildings. The road is situated about 1 km west of the city centre.
5. Pavements to be tested

5.1 Reference pavement
A very important part of a project for development and testing of noise reducing pavements is to define a zero level or a reference pavement, so that the noise of different pavements can be related to this reference pavement. The ISO standard for SPB measurements [6] state, that a reference pavement must be dense smooth-textured asphalt concrete fulfilling the following requirements:

- Maximum aggregate size between 11 to 16 mm (preferably 11-14 mm).
- The texture depth measured as MPD shall be between 0.50 and 1.00 mm (preferably 0.60-1.00).
- The sound absorption coefficient must be less than 0.1 (in praxis not absorbing).
- The build in air-void must be less than 8 %.
- Trafficked at least one year (preferably 2-8 years).

In another EU project (HARMONOISE) a joint European noise prediction method is being developed. In this project reference pavements fulfilling the above requirements are used. In order to relate the results from the Danish test sections to the other results in the European SILVIA project, the SILVIA project group on test sections (Working Package 4.3) has asked the Danish SILVIA.DK project, to include at least one reference pavement with 11 mm aggregates.

The maximum aggregate size is important as there is a tendency that the noise level increases slightly, when the aggregate size is increased.

The definition of a reference pavement has been discussed intensively in the SILVIA.DK project group. From a Danish perspective it is important, that the reference pavement reflects pavements that are typical on urban roads in Danmark. On roads with a traffic volume less than 8,000 - 15,000 vehicles pr. day dense pavements with 8 mm aggregates are typical. If the traffic volume is higher 11 mm aggregates are typical. But there is no exact shifting point between the use of 8 and 11 mm aggregates.

It is unusual to use 16 mm aggregates on urban roads. At the existing Danish test road with twin-layer porous pavements (Oster Søgade project) a reference pavement with 8 mm aggregates is used.

In order to cover the typical situations in Danish cities and in order to investigate the difference between reference pavements with 8 and 11 mm aggregates, it has been decided to include both types in the Danish project. This will also meet the proposal from WP2 in the SILVIA project.

5.2 Development of test pavements
The development and design of the recipes for the pavements to be tested in the project have been based on a combination of the best available knowledge and technology in Denmark combined with a study of the latest experiences in the Netherlands as well as a study of literature from other European countries (supplied by the partners in
SILVIA). A two day study tour to the Netherlands has been undertaken in May 2003. The results of this tour are published in a separate SILVIA document [7].

The goal is to develop pavements fulfilling the following functional requirements:

1. Pavements with as smooth a top surface as possible in order to minimize the noise generated by vibrations in the tires. In order to achieve this, pavements with a maximum aggregate size of 6 mm have been selected.
2. Pavements with as open a surface as possible in order to minimize the noise generated by the air pumping effect. In order to achieve this, pavements with a very open top structure have been selected. The pavements are open but not porous with an open structure in the whole layer thickness of the pavement. In one of the test pavements a certain amount of larger aggregates (size 5-8 mm) have been added, in order to increase the openness of the top structure.

Three different types of thin open pavements are included in the project:

1. Open graded asphalt concrete (AC-open) with a (built in) Marshall air void of approx. 8 - 14 %.
2. Split Mastics Asphalt (SMA) with a (built in) Marshall air void of approx. 4-8 %.
3. A thin layer constructed as a combination pavement (TP). On the existing road surface a thick layer of polymer modified bitumen emulsion (including water) is laid out. On the top of this a very open SMA pavement (like porous asphalt) with a (built in) Marshall air void of approx. 14 % or even more is applied. The bitumen layer “boils up” in the air voids of the SMA pavement leaving only the upper part of the SMA structure open. This reduces the built in air void of the SMA because the pores of the pavement are filled with bitumen.

In order to achieve low costs standard bitumen will be used. The bitumen will be in the soft end of the spectra, in order to achieve a good lifetime for the pavements. Cement will be added to the bitumen in order to improve the adhesion of the bitumen. In some of the pavements elastomer modified bitumen will be used in order to improve flexibility and durability.

These three types of pavements are tested on each of the three test roads (in Århus only two pavement types). But there are slightly differences in the three cities in order to test different modifications of the same pavements. These modifications are called type A (in Copenhagen), type B (in Randers) and type C (in Århus).

The pavements tested in Copenhagen (type A), in Randers (type B) and in Århus are quite similar, but there are slight differences. In Copenhagen “Vikan” aggregates from Sweden are used. In Randers “Durasplit” aggregates form Norway are used. The aggregates are produced from crushed rock. In Århus Danish steelslags is used for the AC6 open Type C and “Norit” crushed rock from Norway for the SMA Type C.

For the open pavements (AC6 open) there is a difference in the amount of bitumen used in type A, B and C.
5.3 The test pavements

Table 2. The test pavements in Copenhagen. Specified data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Aggregate size</th>
<th>Bitumen</th>
<th>Thickness approx.</th>
<th>Weight</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC11 dense (reference)</td>
<td>11 mm</td>
<td>70/100 (B85)</td>
<td>30 mm</td>
<td>70 kg/m²</td>
<td>Skanska</td>
</tr>
<tr>
<td>AC8 dense (reference)</td>
<td>8 mm</td>
<td>70/100 (B85)</td>
<td>25 mm</td>
<td>55 kg/m²</td>
<td>Skanska</td>
</tr>
<tr>
<td>AC6 open Type A</td>
<td>6 mm</td>
<td>160/220</td>
<td>20 mm</td>
<td>45 kg/m²</td>
<td>Skanska</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,5 % elastomer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMA Type A</td>
<td>6 mm +5/8 mm</td>
<td>70/100</td>
<td>20 mm</td>
<td>45 kg/m²</td>
<td>Skanska</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP6 Type A</td>
<td>6 mm</td>
<td>100/150</td>
<td>17 mm</td>
<td>35 kg/m²</td>
<td>Skanska</td>
</tr>
</tbody>
</table>

Table 3. The test pavements in Randers. Specified data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Aggregate size</th>
<th>Bitumen</th>
<th>Thickness approx.</th>
<th>Weight</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC11 dense (reference)</td>
<td>11 mm</td>
<td>70/100 (B85)</td>
<td>30 mm</td>
<td>70 kg/m²</td>
<td>NCC</td>
</tr>
<tr>
<td>AC6 open Type B</td>
<td>6 mm</td>
<td>160/220 + 1,5 % elastomer</td>
<td>20 mm</td>
<td>45 kg/m²</td>
<td>NCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMA Type B</td>
<td>6 mm +5/8 mm</td>
<td>100/150</td>
<td>20 mm</td>
<td>45 kg/m²</td>
<td>NCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP6 Type B</td>
<td>6 mm</td>
<td>100/150</td>
<td>17 mm</td>
<td>35 kg/m²</td>
<td>NCC</td>
</tr>
</tbody>
</table>

Table 4. The test pavements in Århus. Specified data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Aggregate size</th>
<th>Bitumen</th>
<th>Thickness approx.</th>
<th>Weight</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC11 dense (reference)</td>
<td>11 mm</td>
<td>70/100</td>
<td>35 mm</td>
<td>90 kg/m²</td>
<td>Colas</td>
</tr>
<tr>
<td>AC8 dense (reference)</td>
<td>8 mm</td>
<td>70/100</td>
<td>20 mm</td>
<td>50 kg/m²</td>
<td>Colas</td>
</tr>
<tr>
<td>AC6 open Type C</td>
<td>6 mm</td>
<td>160/220</td>
<td>18 mm</td>
<td>45 kg/m²</td>
<td>Tarco</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+3,5 % elastomer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMA Type C</td>
<td>6 mm</td>
<td>100/150</td>
<td>20 mm</td>
<td>45 kg/m²</td>
<td>Colas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+3,0% elastomer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the SMA pavements the type B is more open than type A with 27 % of the material being less than 2 mm. For type B 22 % of the material is less than 2 mm. For type C only 16 % of the material is less than 2 mm. The bitumen content in type A is 6.7 %, in type B 7.5 % and in type C 8.3 %. For the thin layer constructed as a combination pavement (TP) there is a difference in the content of stones and bitumen. In type A there are more stones with 22 % of the material being under 2 mm. For type B 26 % of the material has a size under 2 mm.
6. Hypotheses

The project will be designed in order to test the following hypotheses for urban roads:

1. Open thin layers have a noise reducing capacity compared to dense asphalt concrete.
2. The noise reducing capacity of open thin layers is less than the noise reducing capacity of twin-layer porous pavements.
3. The open thin layers with the most open surface structure have the best noise reducing capacity.
4. Open thin layers keep the noise reducing effect over the structural lifetime of the pavements.
5. Open thin layers have the same structural lifetime as ordinary dense pavements.
6. Roads in urban areas with open thin layers have the same traffic safety level as dense asphalt concrete.
7. There are no special problems with winter maintenance on open thin layers compared to dense asphalt concrete.
8. The rolling resistance and by that the energy consumption of the vehicles is the same on open thin layers and on dense asphalt concrete.

The detailed investigations and the measurement program will be designed in order to be able to test these hypotheses. The SILVIA project only lasts for 3 years. This determines that it will only be possible to test these hypotheses over a period covering the first two years of the lifetime of the test pavements.

If the results are positive it is the hope of the project group, that it will be possible to find economical resources to continue the project, in principle order the whole lifetime of the pavements tested.
7. Working plan

7.1 Activities already carried out
The following activities have been carried out in the first year of the SILVIA project and in connected projects covering the period from August 2002 to July 2003:

- Establishment of Danish project group.
- Two meetings in the Danish project group.
- Selection of test roads.
- Survey on literature about thin open layers.
- Tour to the Netherlands in order to study thin open layers from an acoustical as well as a technical and design perspective [7].
- Development of recipes for test pavements.
- Development of project description as well as measurement program, working plan and project layout.
- General approval of the layout of the Danish SILVIA.DK project by the SILVIA WP4 working group at a meeting in Stockholm June 2003.
- Construction of the test sections in Copenhagen in June 2003.
- Construction of the test sections in Randers in July 2003.
- Construction of the test sections in Århus August 2003.

7.2 Activities in the future
The following activities are so far planned to be carried out in the second and third year of the SILVIA project covering the period from August 2003 to July 2005:

- September 2003. Final approval of the project description by the project group.
- September-October 2003 year zero measurements.
- September 2003 visual inspection of pavements.
- December 2003 presentation of the project at “Vejforum” the yearly Danish road conference.
- May 2004 visual inspection of pavements.
- June 2004 presentation of the project at the congress of the Nordic Road Association.
- June 2004 June-August 2004 year one measurements.
- August 2004 presentation of the project at “Trafikdage in Ålborg”, the yearly Danish traffic congress.
- May 2004 visual inspection of pavements.
- Mai-June 2005 year two measurements.
- July 2005 final report.
- December 2005 presentation of the project at “Vejforum” the yearly Danish road conference.
- August 2005-July 2006 presentation of results at conferences and in articles (after the termination of the EU SILVIA project).
8. Measurement program

The measurement program has been developed in order to obtain results that can highlight the hypotheses (see chapter 6) and in the end confirm or reject the hypotheses. The program has a comprehensive approach and is planned to cover:

- Noise
- Structural behaviour of the pavements
- Durability
- Traffic safety
- Energy consumption

8.1 Noise
The central noise measurements will be carried out using the so-called “Statistical Pass By Method” (SPB method) [6], where the noise of the actual vehicles on the road is measured at the side of the road. By this method noise levels that are relevant for the description of the noise in front of the facade of dwellings in the areas along roads are measured.

As a supplement to the SPB measurements, it is the intention that the noise will also be measured in year 1 using the so-called “close proximity method” (CPX method), where a trailer is pulled after a car. The trailer is insulated and equipped with microphones measuring the near field of the noise generated by the tire road interaction. This method can be used for ranking of pavements according to the near field noise, but the results can not be directly used to predict the noise in front of the facade of dwellings in the areas along roads.

8.2 Traffic safety
Traffic safety is not a crucial part of the Danish test of thin open layers. However some measurements of factors related to traffic safety is planned:

- Measurements of the skid resistance on the different test pavements.
- Measurements of noise inside a passenger car while it is driving on the test sections with constant speed. The method described in the relevant ISO standard will be used [8]. It must be expected, that the noise level inside a vehicle (together with other parameters) has some influence on the speed selected by the driver, and there is a general relation between speed and the risk for accidents to occur. For trucks and busses the engine noise is considered the primary source to noise inside the vehicle, so the tire road noise is not considered very important for these heavy vehicles and therefore these vehicle types are not included.
- Visual inspection to register systematically the splash and spray when vehicles are driving on the pavements in a wet condition. A simple method using digital photos as documentation will be developed. It must be expected, that the less splash and spray there is on a pavement the better a sight the drivers have to the road and to
other vehicles driving on the road. Therefore it must be expected that the less splash and spray there is the road the better is the traffic safety level.

- A minor traffic accident survey of the test roads covering a two year period before the test pavements were constructed and the two year period after they were constructed from August 2003 to June 2005.

8.3 Material
The composition of the material (fine material, aggregates, bitumen) actually used for the construction of test pavements will be analysed.

8.4 Structure
The surface texture will be measured by laser equipment as well as by the use of the “sand patch method”. The measurements will cover MPD as well as texture spectra at short sections near the noise measurement positions.

8.5 Energy consumption
In order to estimate the level of energy consumption on the test pavements it is the intention to measure the rolling resistance. The plan at the moment is to use some measurement equipment being developed by the Technical University of Gdansk in Poland. The equipment is built into a trailer, which is pulled after a car. These measurements will be performed if the equipment is functional and will be available for the project.

8.6 Winter performance
In order to monitor the performance of the pavements during the winter period and the winter maintenance a logbook will be frequently updated by the road administrations with relevant information based upon subjective judgements.

8.7 Monitoring and inspection
In order to evaluate the structural performance and the aging process of the pavements, visual inspections will be made on the test sections and a systematic status form will be updated. A standard form will be used for this. The factors monitored will be the tendency for ravelling, the surface structure, accumulation of dirt in the surface structure of the pavements, damages and a valuation of remaining lifetime. On the background of this a rough evaluation of the lifetime of the pavements can be performed.
Table 5. Measurement program on the test pavements in Copenhagen.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
<th>Executing organisation</th>
<th>Financed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPX noise measurements</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Land</td>
<td>?</td>
</tr>
<tr>
<td>Texture measurements by laser</td>
<td>Sept./Oct. 2003, May 2005</td>
<td>Danish Road Institute</td>
<td>Road and Park Division Copenhagen</td>
</tr>
<tr>
<td>Material analyses</td>
<td>Sept./Oct. 2003</td>
<td>Skanska</td>
<td>Skanska</td>
</tr>
<tr>
<td>Skid resistance</td>
<td>Sept./Oct. 2003, April 2005</td>
<td>Danish Road Institute</td>
<td>Skanska</td>
</tr>
<tr>
<td>Noise inside vehicles</td>
<td>Oct. 2003, May 2005</td>
<td>Atkins</td>
<td>Atkins part of SILVIA (EU/Atkins)</td>
</tr>
<tr>
<td>Rolling resistance</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Land</td>
<td>?</td>
</tr>
<tr>
<td>Splash and spray</td>
<td>May/June 2004, May/June 2005</td>
<td>Road and Park Division Copenhagen</td>
<td>Road and Park Division Copenhagen</td>
</tr>
<tr>
<td>Traffic accident survey</td>
<td>June 2005</td>
<td>Atkins</td>
<td>Atkins part of SILVIA (EU/Atkins)</td>
</tr>
<tr>
<td>Logbook of winter performance</td>
<td>Winter month 2003/2004 and 2004/2005</td>
<td>Road and Park Division Copenhagen</td>
<td>Road and Park Division Copenhagen</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>September 2003, May 2004, May 2005</td>
<td>Road and Park Division Copenhagen and Skanska</td>
<td>Road and Park Division Copenhagen and Skanska</td>
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</table>
Table 6. Measurement program on the test pavements in Randers.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
<th>Executing organisation</th>
<th>Financed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPX noise measurements</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Poland</td>
<td>?</td>
</tr>
<tr>
<td>Material analyses</td>
<td>Sept./Oct. 2003</td>
<td>NCC</td>
<td>NCC</td>
</tr>
<tr>
<td>Skid resistance</td>
<td>Sept./Oct. 2003, April 2005</td>
<td>Danish Road Institute</td>
<td>NCC</td>
</tr>
<tr>
<td>Noise inside vehicles</td>
<td>Oct. 2003, May 2005</td>
<td>Atkins</td>
<td>Atkins part of SILVIA (EU/Atkins)</td>
</tr>
<tr>
<td>Rolling resistance</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Poland</td>
<td>?</td>
</tr>
<tr>
<td>Splash and spray</td>
<td>May/June 2004, May/June 2005</td>
<td>Road Division Randers</td>
<td>Road Division Randers</td>
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<tr>
<td>Traffic accident survey</td>
<td>June 2005</td>
<td>Atkins</td>
<td>Atkins part of SILVIA (EU/Atkins)</td>
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<tr>
<td>Logbook of winter performance</td>
<td>Winter month 2003/2004 and 2004/2005</td>
<td>Road Division Randers</td>
<td>Road Division Randers</td>
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<td>Visual inspection</td>
<td>September 2003, May 2004, May 2005</td>
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Table 7. Measurement program on the test pavements in Århus.

<table>
<thead>
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<th>Activity</th>
<th>Time</th>
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<th>Financed by</th>
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<tr>
<td>SPB noise measurements</td>
<td>Sept./Oct. 2003, May 2005</td>
<td>Atkins</td>
<td>Road Division Århus</td>
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<td>CPX noise measurements</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Poland</td>
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<tr>
<td>Material analyses</td>
<td>Sept./Oct. 2003</td>
<td>Colas and Tarco</td>
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<tr>
<td>Skid resistance</td>
<td>Sept./Oct. 2003, April 2005</td>
<td>Danish Road Institute</td>
<td>Colas and Tarco</td>
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<td>Noise inside vehicles</td>
<td>Oct. 2003, May 2005</td>
<td>Atkins</td>
<td>Atkins part of SILVIA (EU/Atkins)</td>
</tr>
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<td>Rolling resistance</td>
<td>June/July 2004</td>
<td>Technical University of Gdansk/Poland</td>
<td>?</td>
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<tr>
<td>Splash and spray</td>
<td>May/June 2004, May/June 2005</td>
<td>Road Division Århus</td>
<td>Road Division Århus</td>
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<td>Traffic accident survey</td>
<td>June 2005</td>
<td>Atkins</td>
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<td>Logbook of winter performance</td>
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<td>Road Division Århus</td>
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<td>Visual inspection</td>
<td>September 2003, May 2004, May 2005</td>
<td>Road Division Århus, Colas and Tarco</td>
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</tr>
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</table>

8.8 Documentation

Short technical notes will be produced as documentation for each of the measurements that will be carried out as parts of the comprehensive measurement program. It is the responsibility of the executing organisation to produce these notes. At the end of the project in 2005 Atkins will produce a final report as a SILVIA document in English with the results of the whole comprehensive measurement program. The report will include a test of the hypotheses on the background of the measurement results.

Evaluation and analyses of the lifetime costs of open thin layers in relation to dense asphalt concrete as well as cost benefit analyses might to some extent be included in work package 3 in the SILVIA project.
9. References


[7] Dutch experience with thin layers as noise reducing pavements. Notes from a study tour. SILVIA-DTF.ATKINS-004-01-WP4-07.05.03-Notes study tour Netherlands.

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<td>Jørn Raaberg, Ole Grann Andersen, Jan-Ole Nielsen, Asfaltindustrien</td>
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<td>Bjarne Schmidt</td>
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<td>Tilstandsvurdering af udvalgte kunststofbelægninger</td>
<td>Jeanne Rosenberg</td>
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<td>Susanne Baltzer, Brian Henriksen, Ole Fog</td>
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<td>Jørgen Banke</td>
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<td>Bent Andersen, Hans Bendtsen, Bjarne Schmidt, Carsten Bredal Nielsen</td>
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<td>Bent Andersen</td>
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<td>Rolling resistance, fuel consumption - a literature review</td>
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<td>The DRI – DWW Noise Abatement Program - Project description</td>
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